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Sublittoral mussel settlements in Kandalaksha Bay of the White Sea

by V.V. Oshurkov and V.V. Lukanin

Mytilus edulis L., one of the most common species of bivalves in the littoral and upper sublittoral of the White Sea, is interesting in many respects. First of all, mussel biocoenoses, which are among the most highly productive, have a significant effect on pelagic and benthic communities [K.A. Voskresensky, 1948; A.N. Golovkin et al., 1973; V.N. Galkina, 1979]. Secondly, mussels are the main component of the fouling organisms on hydraulic structures in the coastal areas of the temperate waters [G.B. Zevina, 1972; O.G. Reznichenko, 1979]. Finally, mussels are regarded as a potential item of aquaculture in the Barents Sea [I.Ya. Agarova, 1979], the White Sea [B.L. Kunin, B.I. Sirenko, 1978] and the Sea of Japan [Yu.E. Bregman, S.N. Sidorenko, 1979]. It would seem that the ecology of Mytilus edulis has been studied quite well, but this is not so. There are still some inconsistencies regarding the vertical distribution of Mytilus edulis settlements. Some authors [V.N. Zatsepin et al., 1939; Z.G. Palenichko,

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*The numbers in the right-hand margin are the pages of the Russian text – translator

1947; T.A. Matveyeva, 1948; V.V. Kuznetsov, 1960] have noted that the mussels settle mainly in the littoral zone; they settle in the sublittoral in exceptional cases. At the same time, the data of bottom-sampling stations indicate that they have been found at a depth of 102-265 m [K.M. Deryugin, 1928; L.A. Kudersky, 1961] and even at a depth of 1450 m in the Sea of Okhotsk [O.A. Skarlato, 1960]. There have recently been a number of papers on the ecology of the local mussle settlements in Kandalaksha Bay of the White Sea [T.L. Beèr , 1979; N.V. Maksimovich, 1979], but they do not cover the whole diversity of the biotopes characteristic of the White Sea. Furthermore, they contain hardly any data on the combination of factors that determine the spatial-temporal distribution of Mytilus edulis in the White Sea.

This prompted us to begin studying the local settlements of M. edulis. The purpose of this particular investigation was to characterize the sublittoral mussel banks in Kandalaksha Bay of the White Sea.

Material and method. Our investigation was conducted in August—October 1979 at the White Sea Biological Station of the Zoological Institute of the USSR Academy of Sciences. Large M. edulis settlements covering an area of hundreds and thousands of square metres were studied in greatest detail. The mussels were collected by means of the diving-quantitative method [A.N. Golikov, O.A., Skarlato, 1965] with the use of a metal 1/40 m^2 frame. Twenty-six quantitative samples from 14 areas of Kandalaksha Bay were analyzed. We determined the individual size, weight and age of the mussels by counting the annual growth

rings, though this method has been criticized by some authors [V.N. Zolotarev, 1972].

Water salinity was measured in the study areas at the levels from which the mussel samples were taken.

Some characteristics of the sublittoral mussel settlements in Kandalaksha Bay of the White Sea

Station No.	Study area	Salinity, ‰	Max. depth m	Area covered by settlement, thou. m^2	Average biomass (n= 2-3), kg/m^2	Average density of settlement, spec/m^2	Max. age of settlement, yr
	Estuarine areas						
4, 5	Dolgaya Luda Is.	14,4—17,4	5	2,5—3,0	19,3	2160	8
6—10	Oleniy Is.	12,0—15,1	5	10— 12	20,0	3080	12
18, 19	Knyazhaya Guba*	4,3—18,2	7	120—130	30,4	2760	9
23	Malaya Pir'ya Guba	17,7	5	6— 8	20,8	8520	4
24, 25	Umba R.	5,2—24,2	15	80— 90	18,2	2700	10
37, 38	Luven'ga settlement	18,0—19,2	5	10— 12	32,5	2700	8
	Sea areas						
16	Varley Is.	22,8	0,7	0,6— 0,8	24,1	8120	5
22	Kovda Guba	20,8	0,6	2,0— 2,4	25,6	2760	8
26	Padan Guba	25,6	2,5	4,0— 6,0	19,7	2160	7
31, 32	Pedunikha Guba	24,3	2,5	7,2—10,5	59,3	3800	8
34, 35	Kupchinnyi porog**	23,7—24,0	1,0	7,5— 8,0	21,4	2880	6
36	Chupa Guba	22,3	1,0	0,5— 0,7	10,7	10356	4

*Russian word for **bay, gulf or inlet;**
Russian word for **rapids - transl.

Results. In the sublittoral, large mussel settlements (mussel banks) were discovered mainly in the areas characterized by a higher than usual water exchange. One group consists of estuarine settlements that live in the low salinity conditions of the surface waters (4.1-17.9‰), and the other of banks located in the inlets and straits where strong tidal currents occur. The water salinity at the surface in these biotopes varies from 20.8 to 26.3‰, i.e. it approximates the normal salinity for the White Sea (see table).

The settlements of the areas being compared have a number of specific features. First of all, the estuarine banks occupy larger areas than the sea banks. Secondly, in the places where the surface layer is highly freshened, the banks begin in the sublittoral at a depth of 0-1.5 m (Fig. 1, a) and spread to a 7-metre depth on the average. In the Umba area, a mussel bank goes down to a depth of 15 m. On the other hand, "sea" banks, in which the upper boundary is confined to the middle horizon of the littoral, extend to a 1—2-metre depth in the sublittoral (Fig. 1, b). Thirdly, the average age of the mussel banks in the freshened areas is usually greater than in the unfreshened areas. (7)

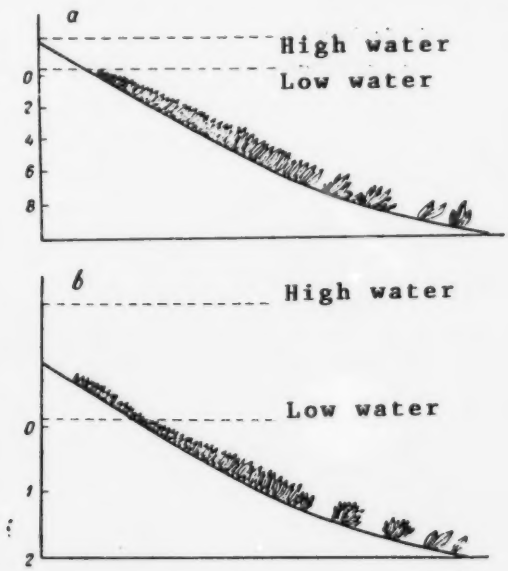

Fig. 1. Vertical distribution of M. edulis settlements in Kandalaksha Bay: a - in estuarine areas, b - in slightly freshened areas. Depth in metres marked on the Y-axis.

While studying the sublittoral mussel settlements, we found that the "Mytilus edulis" biocoenosis is replaced by the

"Laminaria saccharina and L. digitata" or "Balanus crenatus" biocoenoses chorologically. At the boundary of the two biocoenoses, we see a change in the type of aggregation of the mollusks. The typical mussel "brush" constituting the nucleus of the bank thins out, and the mussels form a multitude of small groups in the form of clusters. When comparing the age composition of the mollusks in different types of settlements, we found that animals of older age groups predominated in density in the "brushes", and young specimens predominated in the clusters (Fig. 2), though old mussels dominated in both cases with respect to biomass.

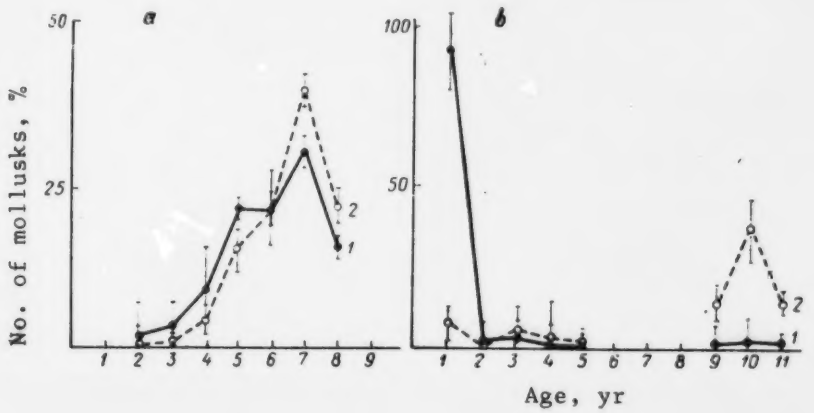

Fig. 2. Distribution of density (1) and biomass (2) of different age groups: a - "brush" aggregation, b - "cluster" aggregation

In order to establish the spatial structure of the sublittoral mussel settlements, a vertical section was executed through a bank located in the strait separating Oleniy and Telyachiy islands in the innermost part of the bay. This settlement of mussels extended from a depth of 0 to 5 m, ard occupied an area of 10,000-12,000 m^2. With an increase in depth, the density of

the settlement decreased, and the biomass increased (Fig. 3), attaining the maximum value (20 kg/m^2) at a depth of 4 m. At a depth of 4.5 m, the mussel bank thinned out and lenses of coarse gravel appeared; finally, at a depth of 5-6 m, only individual small clusters of 8—14-year-old mollusks were encountered amidst the rhizoids of Laminaria.

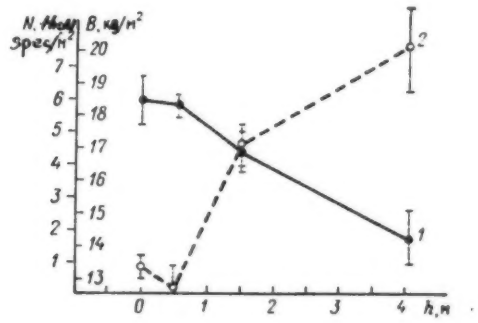

Fig. 3. Changes in density N (1) and biomass B (2) of mussels in the sublittoral with depth

Analysis of the age structure of the given settlement has shown that 4—6-year-old specimens dominate in number at the water line (71.4% of all the mollusks) (Fig. 4, a). Four-year-olds predominate at a depth of 0.5 m (Fig. 4, b). Many empty shells filled with silt (up to 94 per sample) were found amidst the live mussels. As the depth increased, we observed a relative increase in the numbers of older mollusks (Fig. 4, c-d), the structure of the settlement approximating that of a cluster at a depth of 4 m. A large number of young specimens (1-3 years old) was found alongside the old mollusks (8-13 years old) which constituted 42% of the total numbers. On the other hand, there were not very many 5—7-year-olds which are commonly found in the

(8)

superjacent horizons. Similar age correlations were also noted in the samples from the 3—7-metre horizons in Knyazhaya Guba, in the innermost part of Kandalaksha Bay (Dolgaya luda) and in the Umba estuary.

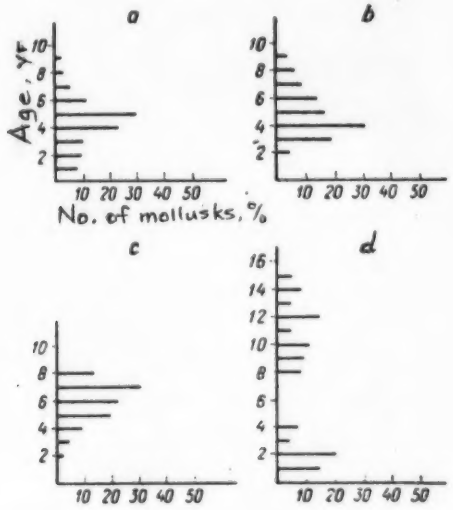

Fig. 4. Age structure of a sublittoral mussel settlement: a - depth 0 m, b - 0.5 m, c - 1.5 m, d - 4 m

The estuarine "M. edulis" biocoenoses are characterized by a poor species composition. In addition to the mussels, we encounter starfish of the species Asterias rubens and barnacles of the species Balanus crenatus which settle both on rocks and on mussel shells. The biomass of Balanus crenatus often reaches 2-2.4 kg/m^2. Starfish are usually scarce on the mussel bank itself, but their density increases drastically at the boundaries of the mussel settlement. According to the observations of divers, a large concentration of starfish is encountered only in the places where the mussels are for some reason stunted and do not form a continuous "brush".

"Sea" mussel banks occupy mostly the littoral, and do not descend below 2.5 m in the sublittoral. At the boundary of these biotopes, we encounter mainly 1—3-year-old individuals, the density of which reaches 10,000-30,000 specimens/m^2, and the biomass 6-14 kg/m^2 (Kovda, Pedunikha and Voron'ya inlets; Ryashkov Is.). Older mussels prevail at greater depths; their density is smaller by an order of magnitude, and their biomass 1.5-2 times higher than in the superjacent horizons.

The fauna and flora of these mussel banks are highly abundant, both in quantity and quality. The Laminaria zone, which usually begins at the 3-5 m level, ascends to the 1-2 m level here. Macrophytes (Laminaria saccharina, L. digitata, Rhodymenia palmata, Chorda filum) often attach to mussel shells. This has been observed in the areas of Tsarsky porog (Kovda inlet), Kupchinnyi porog (Bab'ye Sea) and the rapids in the Pedunikha inlet. In the latter case, the mussel settlement turned out to be 2—3-layered and 10-15 cm thick. Here the algae, which are usually attached to the upper layer of mussels, had a biomass of 2.7-3.0 kg/m^2, while the biomass of mussels at 1.5 m amounted to a record 59.3 kg/m^2. In addition to algae, the "M. edulis" biocoenosis included several species of polychaetes (Nereis pelagica, Eulalia viridis, Lepidonotus squamatus), bivalves (Musculus laevigatus, Musculus sp.), barnacles (Balanus crenatus, B. balanus), starfish (Asterias rubens), and gastropods (Buccinum undatum). (9)

Far from all the shallow straits contained sublittoral mussel banks, though it would seem that they had all the conditions for this. There were no mass concentrations of mussels at Gorodetsky

porog, in the vicinity of Nil'mo inlet, or in Chernaya R.; mussel banks were very scarce in the straits of Kovda inlet, and small mussel settlements were encountered only in "harbor"-type narrowings of inlets along the Kandalaksha shore.

Discussion. The studied sublittoral mussel settlements in the areas where constant surface freshening is observed extend to a depth of 10-15 m. In areas where there is no freshening, the mussels settle predominantly in the littoral, and in the sublittoral descend to a very small depth. This is due to a series of biotic and abiotic factors, the primary ones being salinity, temperature, competition with macrophytes (particularly the family Laminariacea), and predation by starfish and water fowl [V.V. Kuznetsov, 1960; A.N. Gorin, 1975; R. Seed, 1976].

The decrease in surface water salinity, which in estuarine areas can extend to a depth of 10-15 m, can apparently have a more adverse effect on macrophytes [V.P. Drobyshev, 1972], than on a euryhaline species such as M. edulis [V.V. Lukanin, 1971]. In places where there is no freshening, the mussel bank is forced out by Laminaria to the littoral, or at least to a depth not greater than 1-2 m. The mechanism of this type of topical interrelations is not quite clear. One can assume, on the one hand, that the thalluses of Laminaria and other macrophytes which attach to the mussel shells help the mollusks to break away from the substrate and move to other habitats. The basic mechanism of this phenomenon has been described [E. Fischer-Piette, 1935]. On the other hand, there may be a chemical interaction between the mollusks and algae, one which is known for other groups of

aquatic organisms [Z.S., Kucherova, 1969; J.B. Jackson, 1975]. The decrease in seawater salinity also reduces predation pressure (starfish) which under normal conditions (no freshening, moderate flow rate) limits the spreading of the mussels to the sublittoral [T.L. Beèr, 1979].

Temperature has a significant effect on mussel distribution in the sublittoral. The migration of mussels to significant depths in estuaries may be caused by a warm river run-off rich in organic matter. For instance, mussels are common in the biocoenosis of fouling organisms at a depth of 10-20 m in the warmer Sea of Japan [A.N. Gorin, 1975]. At the same time, the discovery of mussels even in the form of clusters in the lower sublittoral and in the pseudoabyssal of the White Sea [K.M. Deryugin, 1928; L.A. Kudersky, 1961] does not contribute to our understanding of the formation and spatial-temporal distribution of the mussel population in this basin. At best, the mollusks existing under constantly low temperature conditions can "survive" for a certain length of time, having lost their capacity to grow and reproduce [A.N. Savilov, 1953; R. Seed, 1976; N.V. Maksimovich, 1979; B.N. Sirenko, O.A. Saranchova, 1979]. On the other hand, it is apparently possible for individual mussel settlements to exist at considerable depths and outside the estuarine zone in the relatively warm bays of the White Sea (Onega and Dvina bays) where there is also good mixing of the water [Z.G. Palenichko, 1947].

There is no clear explanation for the increase in mussel age as the "bank" descends to the sublittoral. First of all, this could well be due to the active migration of the young individuals,

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caused by overpopulation of the superjacent horizons [B.L. Bayne, 1964]. Clusters consisting of a few older individuals (8—14-year-olds) and spat (1—3-year-olds) probably form. Secondly, the mussels that originally settled in the sublittoral are able to avoid the effect of such adverse factors as recurrent drying, freshening, abrupt temperature changes, overpopulation and predation by birds. This is substantiated by the fact that 17—18-year-old mussels with long 83-86 mm shells have been found at depths of 5-8 m.

Of special interest during the study of the spatial-temporal distribution of M. edulis settlements is the dying off of mussel banks under the effect of natural and anthropogenic factors associated, in the opinion of certain authors, with eutrophication (Z.I. Kobyakova et al., 1973; A.N. Golikov, 1979] and extreme hydrological conditions [M.N. Rusanova, V.V. Khlebovich, 1967]. In many of the areas where large sublittoral mussel settlements had existed earlier [Z.G. Palenichko, 1947], there are now only individual patches of mussels and a multitude of shells. The same picture is observed in the Zapadnaya and Vostochnaya Por'i inlets, in the Chernaya, Kovda, Keret' and Kolvitsa estuaries, and in the shallow channels around Ryashkov Is. where mussels had flourished in the sublittoral comparatively recently. The only evidence of this today are the "mussel" silts with patches of bacterial infection and an abundance of starfish (up to 17—30 specimens/m^2) which are finishing off the mussel banks. At the same time, mussel settlements in the form of "brushes" consisting of 1—3-year-olds are reappearing in some places in the littoral

and in the upper sublittoral. Research into the formation and degradation, as well as the spatial distribution of sublittoral mussel banks can help us to establish the mechanisms of formation of coastal biocoenoses in the White Sea, and is also of interest to specialists dealing with problems of aquaculture.

Summary. 1) Sublittoral mussel settlements in Kandalaksha Bay are encountered mainly in the estuaries of large rivers and in sea channels; 2) Estuarine mussel banks occupy larger areas, and extend to a depth of 7 m on the average or maximum 15 m, while the mussel banks in sea channels are smaller and do not usually extend below 2.5 m; 3) The mussel settlements of estuarine areas persist for a longer time, reaching the age of 8.5 years on the average (maximum 12 years), whereas the ones in sea channels exist for six years (maximum 8 years); 4) Some M. edulis in the sublittoral live to the age of 17-18 years, attaining a 83-86 mm size; 5) Analysis of the age structure of sublittoral mussel settlements indicates that certain cyclic changes take place in the "M. edulis" biocoenosis, but further, more detailed research must be conducted in order to establish the causes of these changes.

The sublitoral mussel settlements in Kandalaksha Bay (the White Sea) are situated mainly in the estuarine and shallow strait regions. The estuarine mussel banks are distributed from 1—2 m to 6—7 m (max. 15 m) below the tidal zone. In this case the intertidal part of settlement is absent. The mussel settlements of strait were founded at depth to 1—2 m below the tidal zone. The possible causes of differences are discussed in the paper.

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